attempt at equilibration they are more or less counteracted or assisted by other natural forces.

"As an illustration I would recognise every special issue of evolution, as, for example, some well-marked variety of animal (say pigeon) or plant (say rose) as the effect of the combination of the usually so-called natural forces in conjunction with the evolutive, as a temporary stable form, so long as environing conditions to which it was subjected remain the same. Hence appears the permanency of some species and races. Subject them, however, to altered conditions, and thus bring an unaccustomed set of forces to bear upon them, *e.g.*, by domestication or cultivation; the forms once so stable soon 'break,' the equilibrium is overthrown, and variations once more ensue. . . . . . .

"After all, therefore, what I have here called evolutive forces in the organic world may prove to be only particular phases of those which conspire to constitute animal and vegetable life. And just as in the vital force itself it is usual to recognise two such phases, viz., the vegetative and reproductive, so the power of development or continual advance or alteration from an assumed type may ultimately appear as particular forms of life-force issuing in those results which we are accustomed to look upon as designed." GEORGE HENSLOW

ON DEEP-SEA THERMOMETERS[*]

THE objects of this paper and of the experiments and observations recorded therein, are:—

1. The ascertainment of the effect of pressure on thermometers used for deep-sea purposes.
2. To obtain a scale whereby observations made by the thermometers now in use could be corrected for pressure.
3. To obtain a scale whereby observations made previously by other thermometers can be utilised.

In the early part of the year 1868 the attention of the Hydrographer of the Navy was directed to the unsatisfactory nature of the deep-sea Six's thermometers then in use.

The objections made to these thermometers were:—

1. Their fragility, the slightest jar or blow often breaking them.
2. The necessity of their being always kept in a vertical position.
3. The uncertainty of the register, the indices being generally capable of being shaken down.
4. Their large size, in connection with friction in passing through the water.
5. The substance they were mounted on, being generally wood, became so swollen by pressure of the water as often to render them incapable of being withdrawn from the case.

It was also considered that in all thermometric observations at great depths we had been "working in the dark," in that we had no idea of the effect pressure had on the instrument, and consequently on the recorded results; and it was reasonable to suppose that as the action of a thermometer was affected *in vacuo*, an opposite effect would be had by placing them under pressure, the more especially as in the one case the pressure of only one atmosphere, or 15 lb. to the square inch, was removed, while in the other the atmospheres would have to be reckoned by hundreds and the pressure by tons. On this point we were not without actual observation; for Mr. Glaisher, during the year 1844, in some experiments made on the temperature of the Thames near Greenwich with delicately constructed instruments, found that the indications of temperature were affected by pressure on the bulb of the thermometers, and that at a depth of only 25 feet, or about three-fourths of an atmosphere, the readings were increased by 2°; but no definite conclusion could be arrived at from these observations in respect to our deep-sea thermometers, beyond the fact that they were liable to be so affected.

It was therefore suggested to the Hydrographer—

1. That the author might be placed in personal communication with different makers in respect to the best construction for the purpose required; and
2. That a series of experiments should be made by placing some thermometers in a hydraulic press in conjunction with one in an hermetically sealed iron bottle (as a standard) and subjecting them to pressure, that they should be kept under pressure sufficient time to allow the thermometer within the bottle to take up the temperature without, and then the whole compared with the standard.

The first suggestion was immediately acceded to; and those makers from whom the Meteorological Department obtained instruments were applied to, and a list of desiderata submitted to each. Three makers responded, and six instruments were ordered from each.

These instruments were sent in (hereafter called the Hydrographic Office pattern), and Mr. Balfour Stewart, of the Observatory at Kew, was consulted as to the *modus operandi* of testing by pressure, and he approved of that already suggested.

A difficulty arose in respect to a hydraulic press—the use of some in London could not be obtained, and others were not adapted to the purpose, so that the testing was deferred, and some of the instruments were sent to H.M.S. *Gannet*, then deep-sea sounding on the edge of the Gulf-Stream, and afterwards some to H.M.S. *Lightning* for her dredging cruise.

On the return of these vessels the conflicting nature of the temperatures obtained from those supposed to exist (as derived from observations in other localities) rendered the necessity of ascertaining the nature and amount of error due to pressure the more imperative.

At this juncture Mr. Casella undertook to have a testing apparatus constructed at his own expense, capable of producing a pressure of three tons to the square inch.

At a meeting of the Committee of the Royal Society, held in the Hydrographer's Room in April, 1869, and at which the plan of operation for testing the thermometers was discussed, that by means of an iron bottle approved. The late Dr. Miller, V.P.R.S., proposed encasing the full bulb in an outer covering of glass containing air, in order to permit the lighter fluid (air) to be compressed without affecting the bulb within, and one such was directed to be made; but instead of the outer casing being filled with air it was nearly filled with alcohol, which being heated to reduce the quantity of air, the bulb was then hermetically sealed. Mr. Casella was also directed to make others that would facilitate the observations.

At the time these experiments were proposed, it was not known that a thermometer had been constructed, at the suggestion of Mr. Glaisher, by the late Admiral Fitzroy's directions, with the view of removing the difficulty of pressure; this was done by encasing the long bulb at the back of the instrument in glass, and nearly filling the space between the case and the bulb with mercury;[*] and one on this principle was then in the Instrument-room of the Meteorological Office; but although some had been used for deep-sea purposes, the further issue of them had been stopped on account of their fragility, and thus the means for obtaining accurate observations were virtually the same as before.

It was decided to test them at pressures equal to the following depths in the ocean, viz., 250, 500, 750, 1,000, 1,250, 1,500, 1,750, 2,000, 2,250, and 2,500 fathoms, the rule to be applied being 33 feet = one atmosphere = 15 lb. on the square inch. From this a table was constructed for use.

On the 4th of May the following thermometers were taken to Hatton Garden, viz.:—

Nos. 56 and 57	Casella .	Hydrographic Office pattern.
66 and 67	Elliott . .	„ „ „
72 and 73	Pastorelli.	„ „ „

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[*] Abridged from a paper read before the Meteorological Society, April 19, 1871, by Capt. J. E. Davis, R.N.

[*] See Meteorological Papers, No. I., 1863.

No. 1	Casella .	Specially made with an extra-thick cylinder bulb to *defy* compression.
3	„ .	Spherical bulb ; extra-thick glass. This thermometer was made, at the special request of one of Mr. Casella's workmen, in order to resist effect by pressure.
4	„ .	Short cylinder bulb : extra-thick glass.
6	„ .	A glass cup fitting over bulb, designed by Mr. Siemens.

All the above were Six's thermometers with the bulbs unprotected.

No. 2	Casella .	Glass-encased bulb, as proposed by Dr. Miller, but with the case nearly filled with spirit.
5	„ .	Long cylinder bulb at the back, encased in glass, and nearly filled with spirit.

These instruments were first compared in air and then immersed in a tub of water, No. 57 being placed in an iron bottle. Set the indices and placed the thermometers in the cylinder of the press, and pumped on a pressure equal to 250 fathoms, and kept it on two hours.

It is useless to record the result of this first experiment; or it may rather be stated that the results were *nil*, except ascertaining the weak points of the process adopted.

The Miller-pattern thermometer subsequently proved so near perfection it was decided to use that as a standard for the Hydrographic Office pattern.*

It was found necessary to reduce the number of thermometers, and also of the readings, to a minimum.

With the view of testing the efficiency of Dr. Miller's pattern (No. 2) it was placed in the cylinder with No. 57, and subjected to a pressure of 4,032 lbs. (about 1,480 fathoms) for a quarter of an hour, with the following result.

EXPERIMENT NO. 1 (pressure = 1,480 fathoms).
Dr. Miller reading.

Thermometer.	Minimum.		Maximum.		Diff. of Max.
	Before.	After.	Before.	After.	
2	47°·5	47°·5	47°·5	48°·0	0°·5
57	47·5	47·5	47·5	55·0	7·5

This experiment at once proved the efficacy of the encased bulb ; and the experiment was repeated with more thermometers, with the same pressure and for the same period of time.

It was found by this experiment that while the mean difference of the encased bulbs was only 0°·95, that of the two made to defy compression was 7°·25, that with the cover 10°·5, the Hydrographic Office pattern the same as in No. 1, 7°·5, and a Phillip's Alpine thermometer 70°·3.

The "Phillip's" was an ordinary make, with a very small bulb ; and the great difference shown by it proved that the amount of compression is in proportion to the thickness of the glass ; but in immediate connection with the subject the experiment clearly demonstrated two facts, viz. :

1. That very nearly all the difference, or error, is due to pressure on the full bulb ; and
2. That by encasing the bulb we have nearly a perfect instrument.

Notwithstanding the satisfactory result obtained in enabling us to decide on a thermometer for future use, it was necessary, if possible, to establish a scale whereby temperatures already taken with instruments of the Hydrographic Office pattern might be corrected for pressure, and also to ascertain if all, or what part, of the difference shown under pressure in the Miller pattern was due to calorific effect produced by sudden compression of the water in the cylinder or by compression of the unprotected parts : preparation was accordingly made to continue the experiments.

It being necessary, as before stated, to reduce the number of the thermometers, and also the readings, to a minimum, the following were selected, viz. :—

Nos. 2 and 5	Casella .	Encased bulbs.
56 and 57	„ .	Hydrographic Office pattern.
73	Pastorelli	„ „ „
67	Elliott .	„ „ „
9641	Casella .	Alpine.

These were attached to a float (to avoid immersing the hand in the water) and placed in the cylinder filled with water, to remain all night ; the cistern, from which the water is pumped into the cylinder, was filled, and also a tub of water for replenishing placed by the side in order that the water in each might be, as nearly as possible, of the same temperature in the morning.

The thermometers were read in the order in which they are placed ; when all were read, the indices were set as quickly as possible, and the instruments at once lowered into the cylinder and the pressure applied.

May 5. The first series of experiments were made, Mr. Casella reading.

FIRST SERIES OF EXPERIMENTS. Errors at different pressures. (*Abridged from original.*)

Thermometer.	No. 1. 250 fms. 682 lbs.	No. 2. 500 fms. 1,363 lbs.	No. 3. 750 fms. 2,045 lbs.	No. 4. 1,000 fms. 2,728 lbs.	No. 5. 1,250 fms. 3,400 lbs.	No. 6. 1,500 fms. 4,089 lbs.	No. 7. 1,750 fms. 4,771 lbs.	No. 8. 2,000 fms. 5,452 lbs.
2	1°·5	2°·1 ?	1°·0	1°·2	1°·2	1°·6	1°·4	1°·6
5	1·3	1·6	0·2	0·6	0·4	0·8	0·8	1·6
56	1·1	2·7	3·8	4·3	5·5	7·0	8·0	9·5
57	1·0	2·7	3·8	4·9	5·6	7·4	8·2	9·7
73	1·9	2·6	4·2	6·0	6·8	8·2	9·7	10·2
67	3·9	7·9	Broken†	...	...	...	...	...
66	...	...	...	...	13·3	16·4	18·7	Broken‡
Phillip's Alpine . .	...	...	...	...	...	...	...	71·0
Thomson § .	...	...	...	...	...	...	...	1·1

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* I was not aware at that time of the existence of the enclosed Phillip's thermometer as designed by Sir Wliliam Thomson.

† The instrument was taken out safely, but while reading off the full bulb cracked right across.

‡ Broke at a pressure equal to 1,848 fathoms.

§ This insulated thermometer is a Phillip's encased in a glass cylinder containing a little spirit, designed by Sir William Thomson.

The thermometers were under pressure for an average time of 37 minutes in each experiment.

May 6.—The following experiment was made with the Hydrographic Office pattern (not used yesterday) for comparison. Mr. Casella reading.

Pressure = 2,000 fathoms = 5,452 lbs. Under pressure seventeen minutes.

Thermometer.	Error.
2	1°·4
5	1·2
53	9·9
58	10·7
71	11·3
74	10·3
75	9·6
Thomson	1·0

SECOND SERIES OF EXPERIMENTS

June 21.—The thermometers were placed in the cylinder, which was filled with water; the supply-tub or cistern for pumping in from, and a tub of water standing near the press, were also filled and thus left all night.

June 22.—A dull morning, with no sun, and all conditions most favourable for observing.

Before commencing, obtained two tubs of water with 12° difference of temperature, and tested the thermometers as to time in taking up heat and contrariwise, and it was found that, by allowing the thermometers to remain under pressure eight minutes, the same results would be obtained as if they were allowed to remain half an hour or more, as in the first series of experiments.

The thermometers used were—

Standard . . .	Casella .	Dr. Miller's pattern.
No. 54 . . .	,, .	Hydrographic Office pattern.
56 . . .	,, .	,, ,, ,,
76 . . .	Pastorelli	,, ,, ,,
73 . . .	,, .	,, ,, ,,
Thomson . . .	Casella .	Encased (Sir William Thomson's design).

SECOND SERIES OF EXPERIMENTS. Errors at different pressures. (*Abridged from original.*)

Thermometer.	No 1. 250 fms.	No. 2. 500 fms.	No. 3. 750 fms.	No. 4. 1,000 fms.	No. 5. 1,250 fms.	No. 6. 1,500 fms.	No. 7. 1,750 fms.	No. 8. 2,000 fms.	No. 9 2,250 fms.	No. 10. 2,500 fms.
Standard .	0°·7	0°·7	1°·2	1°·5	1°·6	1°·5	1°·7	2°·0	2°·0	2°·2
54	1·4	3·1	3·9	5·2	6·4	7·8	8·3	9·7	11·1	12·9
56	1·8	2·8	4·0	5·3	6·3	7·8	8·8	9·9	10·9	12·0
76	1·2	2·5	4·2	4·9	6·3	7·2	8·4	9·6	10·9	11·7
73	1·4	3·0	4·6	4·9	7·4	7 8	10·2	11·5	12·3	13·7
Thomson ,	0·0	0·1	0·0	0·3	0·1	0·5	0·3	0·6	0 8	0·4

The thermometers were under pressure eight minutes in each experiment.

The mean difference for each 250 fathoms by each thermometer is as follows (*abridged*):—

BY FIRST SERIES OF OBSERVATIONS

Thermometer.	Diff.
2	+ 0°·20
5	+ 0·20
56	+ 1·19
57	+ 1·20
73	+ 1·27

BY SECOND SERIES OF OBSERVATIONS.

Thermometer.	Diff.
Standard	+ 0°·22
54	+ 1·29
56	+ 1·20
76	+ 1·17
73	+ 1·37
Thomson	+ 0·05

EXPERIMENTS FOR CALORIFIC EFFECT.

The Phillip's encased maximum thermometers (Thomson's) being entirely protected from any effect by compression, it was decided to ascertain by their means the calorific effect produced by the sudden compression of the water in the cylinder; but, as in the two series of experiments recorded, there was such a gradual increase in the temperature of the air and also in the water used for supplying the cylinder, that for any delicate observation the conditions were not favourable; the observations for calorific effect were therefore delayed until the weather got colder, when a more equable temperature could be ensured throughout the experiment.

In order to ascertain what time it would require for these instruments to take up temperature (as it was of importance they should not be kept under pressure longer than necessary) observations were made for the purpose, and it was found that five minutes would be sufficient time for the Thomson thermometers to take up the most minute portion of heat observable.

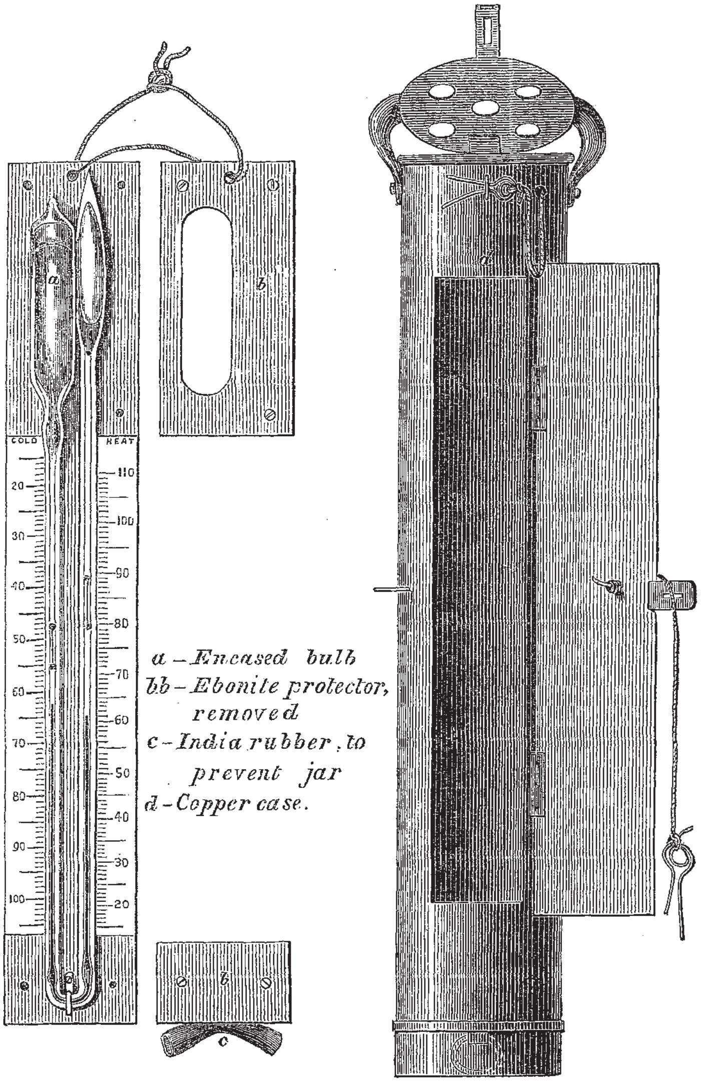
November 12.—The following observations were made day cloudy, all the conditions favourable.

No. 1. Pressure = 2,500 fathoms = 6,817lbs. Under ten minutes.

Thermometer.	Diff.	Remarks.
11,424	+ 0°·1	Temperature in air . . 40°·0
9,649	+ 0·4	,, tub . . 41·6
9,645	+ 0·2	,, cistern. 38·8
		,, cylinder 38·0

EXPERIMENT NO. 2 (same pressure). Under pressure twenty minutes.

Thermometer.	Diff.	Remarks.
11,424	+ 0°·0	Temperature in air . . 43°·6
9,649	+ 0·0	,, tub . . 41·2
9,645	+ 0·2	,, cistern. 41·2
		,, cylinder 38·9



DEEP-SEA THERMOMETER USED BY THE HYDROGRAPHIC OFFICE

It will be observed that the water pumped into the cylinder was a little warmer than that in the cylinder; but as the valve through which it passed into the cylinder is near the top, while the bulbs of the thermometers were at the bottom, the small difference it could have made in the upper water could not have affected them.

BY MR. CASELLA (previously observed).

Thermometer.	Pressure.	Diff.	Remarks.
	fms.	°	
	500	+ 0·2	
	1,000	0·0	
	1,500	0·0	
	2,000	+ 0·2	
	2,000	+ 0·6	
	2,000	+ 0·3	

The result of the foregoing Experiments (some rejected in forming the mean):—

0·0178, calorific effect for each 250 fathoms' pressure.
0·18 „ „ 2,500 „ „

It would seem almost unnecessary, for the purpose for which this paper is prepared, to record the above observations at all, so small is the result; but as the amount of heat caused by compression is supposed by some to be much greater, it has been thought best to give it.

EXPERIMENTS TO DETERMINE THE AMOUNT OF HEAT PRODUCED BY FRICTION.

To ascertain if any error could arise from heat created by friction in a thermometer passing rapidly through the water, one of Casella's Hydrographic Office pattern was towed astern of one of the fast river-steamers (*Naiad*), keeping the thermometer well submerged by means of a lead weight attached to the line before it; and with repeated trials at full speed not the slightest difference could be detected.

The error of the Miller-pattern thermometer as deduced from the observations (some rejected in forming the mean), *abridged*: —

	°
Error per 250 fathoms as shown by hydraulic press	0·161 mean
Deduct for calorific effect	·018
True error for 250 fathoms	0·143
True error for 2,500 fathoms	1·43

Mean Errors of Hydrographic Office pattern Thermometers, by testing-apparatus, corrected for calorific effect:—

Fathoms.	CASELLA.	PASTORELLI.
	°	°
250	1·307	1·482
500	2·789	2 664
750	3·821	4·279
1,000	4·853	5·195
1,250	5·860	6·743
1,500	7·392	7·625
1,750	8·199	9·307
2,000	9·638	10·106
2,250	10 838	11·438
2,500	12 270	12·520

The Progressive Rate of Error of the Hydrographic Office pattern Thermometers, as deduced from the foregoing table, by testing-apparatus, is by Casella, equal to an increase of effect at the rate of 0°·014 per 250 fathoms' pressure; and by Pastorelli, equal to a decrease of effect at the rate of 0° 044 per 250 fathoms' pressure.

Thus, while one set of thermometers show an increase of effect under pressure, the other set denote a decrease, and the mean of the two would be so small a decrease as not to be appreciable; and the practical conclusion is, that, by the testing-apparatus, the elasticity of the glass is in exact proportion to the pressure applied.

OCEAN OBSERVATIONS BY STAFF-COMMANDER E. K. CALVER

Although from the result of the experiments with the testing apparatus, a scale could be formed for the correction of the Hydrographic Office pattern thermometers, that scale may be said to be made under theoretical conditions rather than practical, and as it was necessary to verify its correctness by observations in the ocean, a number of the instruments used in the press were sent on board the *Porcupine* in 1869, and a series of most carefully taken observations were recorded by Staff-Commander Calver at the same depths as the calculated pressure applied in the press.

It is unnecessary to give the details of these observations; it will suffice to give the progressive error derived from the mean of them, and corrected for the error of the standard.

Fathoms.	CASELLA.	PASTORELLI.
250	1·329	1·210
500	2·816	2·986
750	4·002	4·779
1,000	5·427	6·422
1,250	6·286	7·065
1,500	7·058	8·118
1,750	7·301	8·301
2,000	7·711	8·844

The progressive rate of error derived from the above is by Casella, equal to a decrease at the rate of 0·13 per 250 fathoms, and by Pastorelli, equal to a decrease of effect at the rate of 0·09 per 250 fathoms.

This result, contrary to that by the hydraulic press, proves that the elasticity is not regular or in ratio to the pressure, but that after continuing regular up to a pressure of 1,000 fathoms, it decreases in a compound ratio to a pressure of 2,000 fathoms, when its elasticity nearly ceases.

Comparison of the Hydrographic Office pattern Thermometers as found by the hydraulic testing-apparatus and by the Ocean Observations:—

CASELLA.

Pressure.	Error.		Per 250 fathoms.	
	Press.	Ocean.	Press.	Ocean.
fms.	°	°	°	°
250	1·307	1·329	1·307	1·329
500	2·789	2·816	1·394	1·408
750	3 821	4·002	1·274	1·334
1,000	4·853	5·427	1·213	1·357
1,250	5·860	6 286	1·172	1·257
1,500	7·392	7·058	1·232	1·176
1,750	8·199	7·301	1·171	1·043
2,000	9·638	7·711	1·205	0·964
2,250	10·838	...	1 204	...
2,500	12·270	...	1·227	...
Means			1·240	1·233
Error at 2,500 fathoms by the means . .			12·4	12·3

PASTORELLI.

Pressure.	Error.		Per 250 fathoms.	
	Press.	Ocean.	Press.	Ocean.
fms.	°	°	°	°
250	1,482	1·210	1·482	1·210
500	2·664	2·986	1·332	1·493
750	4·279	4·779	1·426	1·593
1,000	5·195	6·422	1·299	1·606
1,250	6·743	7·065	1·349	1·413
1,500	7·625	8·118	1·271	1·353
1,750	9·307	8 303	1·329	1·186
2,000	10·106	8·844	1·263	1·105
2,250	11·438	...	1·271	...
2,500	12·520	...	1·252	...
Means			1·327	1·370
Error at 2,500 Fathoms by the means . .			13·3	13·7

By this comparison, although the errors, as found by the two modes of observation, differ at individual depths or pressure, still the means of Casella's per 250 fathoms are almost the same, and those of Pastorelli's differ only three-tenths of a degree in 2,000 fathoms, the extent to which the comparison can be made.

There can be little doubt that, without the aid of the Miller pattern, by an extended series of observations a scale could have been obtained to correct the Hydrographic Office pattern to a very close approximation of the truth (in accordance with the proposed first intention of the experiments); but the timely suggestion of Dr. Miller has quite set at rest any difference of opinion as to the instrument for future use.

OYSTERS IN IRELAND[*]

HIS Excellency the Lord Lieutenant of Ireland having had represented to him that the artificial propagation of oysters was imperfectly understood in Ireland, appointed in October 1868 Messrs. Blake, M.P., Francis, Hart, and Brady, commissioners to inquire into and report on the artificial cultivation and propagation of oysters.

The instructions to the Commission were to visit the principal places in France, England, and Ireland, where oyster cultivation is or can be carried on, to examine the best authorities on the subject, and to ascertain as far as possible the causes which have led to failures. It was also hinted that three weeks would suffice for Ireland, a

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[*] Report of the Commission appointed to inquire into the Methods of Oyster Culture in the United Kingdom and France, with a View to the Introduction of improved Methods of Cultivation of Oysters into Ireland. (Presented to both Houses of Parliament by command of Her Majesty.) Dublin, 1870.